Forage Res., **47** (1) : pp. 1-10 (2021) **http://forageresearch.in**

CONSERVATION TILLAGE FOR SUSTAINABLE FORAGE PRODUCTION AND SOIL QUALITY IMPROVEMENT: A REVIEW

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(Received : 18 April 2021; Accepted : 10 June 2021)

SUMMARY

Conventional tillage practices lead to change in soil structure by modifying soil bulk density and soil moisture content. Continuous disturbance of soil by conventional tillage makes finer and loose-setting soil structure while conservation and no-tillage methods leave the soil intact which results in a change of characteristics of the pores network. Losses of soil organic C (SOC) and deterioration in other properties exaggerated where conventional tillage was employed whereas conservation tillage improved soil quality. When conventional tillage is replaced by conservation tillage CO_2 emissions from soil is reduced. Conservation tillage is thought to take care of the soil health, plant growth and the environment. Forage crop production could be increased by adopting appropriate tillage operation. Conservation tillage has potential to break the surface compact zone in soil with reduced soil disturbance which leads to a better soil environment and crop yield with minimal impact on the environment and sustainable crop production. Macro- and micronutrients, fiber and protein contents are changed in silage by means of different tillage practices. Generally, conservation tillage has profound effects on forage yield. Zero tillage with mulch, zero tillage without mulch, ploughing, and ploughing plus harrowing had more yield than ploughing plus harrowing twice by 33.7, 30.5, 18.9 and 17.9%, respectively. Conservation tillage lead to lower methane emission in comparison to conventional tillage; on average, 0.32 kg CH_4-C ha^{-1} $year^{-1}$ was oxidized with conservation tillage. Capacity building on innovative conservation tillage practices is crucial for researchers, extension workers, development practitioners and the smallholder farmers.

Key words : Soil organic carbon, conventional tillage, sustainable, forage quality

The intensification of global agriculture has led to a decline in arable land. Globally, intensive agriculture has degraded the soil quality. Holistic management of arable soil is the key to dealing with the most complex, dynamic, and interrelated soil properties, thereby maintaining sustainable agricultural production systems, the lone foundation of human civilization. Any management practice imposed on soil for altering the heterogeneous body may result in generous or harmful outcomes (Derpsch *et al*., 2010).

Unsuitable management practices cause degradation in soil health (depletion of organic matter and other nutrients) as well as decline in crop productivity (Ramos *et al*., 2011). Reducing disturbance of soil by reduced tillage influences several physically (Garrido *et al*., 2012), chemically and biologically (Munoz *et al*., 2007) interconnected properties of the natural body. Soil tillage is among the important factors affecting soil properties and crop yield. Among the crop production factors, tillage contributes up to 20% (Khurshid *et al*., 2006) and affects the sustainable use of soil resources through its influence on soil properties (Lal and Stewart, 2013). The judicious use of tillage practices overcomes edaphic constraints, whereas inopportune tillage may cause a variety of undesirable outcomes, for example, soil structure destruction, accelerated erosion, loss of organic matter and fertility, and disruption in cycles of water, organic carbon, and plant nutrient. Reducing tillage positively influences several aspects of the soil whereas excessive and unnecessary tillage operations give rise to opposite phenomena that are harmful to soil. Therefore, currently there is a significant interest and emphasis on the shift from extreme tillage to conservation and no-tillage methods for the purpose of controlling erosion process.

Globally, agriculture intensification has not only degraded the soil quality but also contributed to increasing the greenhouse gas (GHG) levels. These concerns attract the interest of environmental scientists and academicians to find ways to sequester more carbon (C) in the agricultural soils. Conservation tillage practices can affect biological C sequestration and effects the GHG production.

Effect of tillage on soil properties

The effects of tillage on soil physico-chemical properties are a function of soil properties, environmental conditions and the intensity of the tillage system (Ishaq *et al*., 2002). Courtney *et al*. (2008) reported that no-tillage systems influence water infiltration, soil temperature, soil moisture, soil aeration, nutrient distribution or 'stratification' as well as microbial populations and activity.

Effect of tillage on soil chemical properties

Soil chemical properties are important factors that determine the nutrient supplying capacity of the soil to plants and microbes (Tilahun, 2007). The manipulation of the soil results in several changes and transformations in its chemical properties especially in the long term. It is widely established that soils under long-term no-tillage as well as reduced tillage systems generally contain higher amounts of organic carbon in the soil surface as compared to conventional tillage systems (Thomas *et al*., 2007). The increase in the concentration of soil organic carbon is considered to be the result of different interacting factors, such as minimal soil disturbance, increased residue return, reduced surface soil temperature, higher moisture content and decreased risk of erosion (Blevins and Frye, 1993). Al-Kaisi *et al*. (2005) reported that short-term (≤ 10 years) tillage effects on soil C and N dynamics are complex and often variable. West and Post (2002) attested to the fact that soil C sequestration generally increased by no-tillage practices, but had a delayed response, with a dramatic increase in C after 5-10 years.

In the determination of changes in soil chemical properties under conventional, minimum and no-tillage systems from 1994 to 2004, Benito and Sombrero (2006) reported that changes in soil organic matter were very slow until 1998 where there was no significant difference between organic matter values under tillage systems in the upper 15 cm layer of the soil. Similar results were recorded for soil total N. The authors observed that minimum and no-tillage plots had a higher level of nitrogen compared to conventionally tilled plots. According to them, the phosphorus content showed significant differences in the 10 cm depth of the soil with higher values in mulch tillage and no- tillage as compared to conventional tillage.

Apart from soil organic matter, tillage is reported to affect other chemical properties. No-tillage and conventional tillage systems showed different results with regard to pH, CEC and the concentration of nutrients in the soil. However, these effects are environmentally dependent and therefore different results are reported under different soil types and climates (Limousin and Tessier, 2007; Thomas *et al*., 2007). Tillage can affect the mineralization and decomposition of soil organic matter (SOM) by changing the physical and chemical properties of soils and altering the diversity and activity of the soil microbial community and enzymes, which in turn affects the concentration and composition of soil P (Redel *et al.,* 2011; Wang *et al.,* 2011). Lopez-Fando and Pardo (2009) observed stocks of available P (Bray-1) under no tillage (NT), zero tillage (ZT) and minimum tillage (MT), available P stocks were greatest at the soil surface but decreased rapidly with depth in ZT and MT, whereas under CT no gradient of concentration from the surface to subsurface layers was observed. Comparing four tillage treatments, higher available P concentrations occurred under NT and ZT compared to MT and CT but no significant differences between NT, ZT and MT. They further stated that soil pH and the distribution of SOC, organic N and nutrients in the soil profile (0-30 cm) was altered as a result of various tillage practices being applied for a 5 years period. Ali *et al.* (2018) showed that the various tillage methods had no significant effect on the soil properties.

Effects of tillage on soil physical properties

Generally, under no-tillage system, bulk density increases as no activity to loosen the soil aggregates are performed (Boguzas *et al*., 2010). Courtney *et al*. (2008) reported that no-tillage system influenced water infiltration, soil temperature, soil moisture, soil aeration, nutrient distribution or 'stratification' as well as microbial population and activity.

Tillage affects the soil physical environment through its effect on the physical properties of the soil that further depends up on the inherent characteristics of the soil (Franzluebbers, 2002). Studies comparing no-tillage with conventional tillage systems have given different results for soil bulk density. Several studies showed that soil bulk density was greater in no-till in the 5 to 10 cm soil depth (Osunbitan *et al.* 2005). However, Tripathi *et al.* (2005) found increase in bulk density with conventional tillage in a silty loam soil. Moreover, there are limited studies that examined changes in soil physical properties in response to long- term tillage and management (> 20 year) in the northern Great Plains. Tillage created micro basins can reduce runoff and increase infiltration thereby water available for crop production (Tesfahunegn and Wortmann, 2008). Lopez-Fando and Pardo (2009) observed that after five years of experimentation, no significant differences in bulk density between no tillage (NT), zero tillage (ZT), minimum tillage (MT) and conventional tillage (CT) in 0-5 cm, 5-10 cm and 20-30 cm intervals. Daraghmeh *et al.* (2009) found that compared to conventional tillage, reduced tillage improved soil structure through combi-nation of increased soil organic matter, reduced bulk density and increased proportion of larger aggregates. . Studies have shown zero tillage as an effective practice to increase soil moisture storage (Schwen *et al.,* 2011; Castellini and Ventrella, 2012).

Alvarez and Steinbach (2009) stated that increase of bulk density under no-till in comparison to plow tillage was generally small. The improvement of aggregate stability was higher in poorer structured soils, with an average increase of 70% under no-till in relation to plow tillage. Sharma *et al.* (2011) observed that tillage treatments influenced the water intake and infiltration rate (IR) increased in the order of NT > MT > RB > CT. Hussain *et al.* (2013) reported that bulk density was lowest under disc plough (DP) at 0-15 cm and under minimum tillage (MT) at 15-30 cm soil depth. Adekiya *et al.* (2011) found no significant differences in soil physical and chemical properties but soil bulk density and moisture content significantly influenced cocoyam yield under different tillage systems in a tropical alfisol. Hussain *et al.* (2013) reported that tilled soils had higher tillage induced macro-pores especially in upper soil surface. Vogeler *et al.* (2009) found that the soils under conservation tillage had better pore connectivity and higher saturated hydraulic conductivity than those under conventional tillage.

Influence of tillage practices on forage crop production

Effect of tillage on crop yields is not uniform in all crop species as various soils may respond differently to a tillage practice. Tesfahunegn (2012) experimented out no statistical differences in grain and stover yield of sorghum among different tillage practices. The interaction effects among different tillage treatments with F1 on grain and stover yields were also non-significantly different. Adore *et al.* (1982) carried out field experiments to study the effect of three tillage depths (5, 15 and 30 cm) on yield of maize (*Zea mays*) and sorghum (*Sorghum bicolor*) on a ferruginous tropical soil. An increase in yield of maize by nearly 10% was noticed but yield of sorghum was not affected. Three field experiments were conducted at two locations in late-season 2004, early 2005 and late-season 2006, respectively, on Alfisol (Oxic Tropuldalf) at Owo in the forest-savanna transition zone of southwest Nigeria to estimate the effects of various tillage methods on sorghum grain yields. The treatments consisted of five tillage methods (zero tillage with mulch, zero tillage without mulch, ploughing, ploughing plus harrowing and ploughing plus harrowing twice). Zero tillage with mulch, zero tillage without mulch, ploughing, and ploughing plus harrowing had more yield than ploughing plus harrowing twice by 33.7, 30.5, 18.9 and 17.9%, respectively (Agbede and Ojeniy, 2009).

Field experiments were conducted to determine effect of two relatively new tillage systems on sorghum (*Sorghum bicolor* L.) plant growth and yield. The 3-year mean grain yield for chisel ploughing pooled over the four contour diking distances produced 1448 kg/ha which was greater by 72%, 107% and 384% than broadbed and furrow, ridge-furrow and no-till, respectively (Omer *et al.,* 1997). Intercropping of forage sorghum and cowpea was conducted by Zamir *et al.* (2016). The experiment comprised of two factor, Factor A. Tillage (Main plots), T_1 (Conventional Tillage), T_2 (Deep Tillage) and Factor: B. Seed Ratios (Sub plots) S_1 (Sole Sorghum), S_2 (Sole Cowpea), S_3 (Sorghum 60% + Cowpea 40%) S_4 (Sorghum 70% + Cowpea 30%) and S_5 (Sorghum 80% + Cowpea 20%). In the case of sorghum maximum plant height 273.7 cm and green forage yield 59.9 t ha^{-1} was obtained with treatment sole sorghum and deep tillage. In quality parameter of sorghum crop maximum dry matter yield 15.1 t/ha and crude fiber 38.27% was obtained in treatment sole sorghum and deep tillage. In the case of cowpea deep tillage showed highest plant height (220.33 cm). In cowpea, maximum green forage yield (35.6 t/ha) and dry matter yield (5.4 t/ha) was obtained in deep tillage. Maximum mixed green forage yield (73.6 t/ha) and total dry matter yield (17.1 6 t/ha) was obtained in treatment S_4 and T_2. So, it is concluded that seed ratios S_4 give maximum yield with deep tillage T_2.

Schlegel *et al.* (2018) evaluated the effect of 3 long term tillage intensities and found that on an average, there was an advantage of 120% sorghum yield for NT over CT, 41% NT over RT, and 55% RT over CT. Sorghum yields were 80% higher for continuous NT compared with short term NT (2001–2015 RT). Sojka *et al.* (1997) hypothesized that soil properties affecting forage oat (*Avena sativa cv. Awapuni*) establishment on land compacted by 15 years of conventional cropping might be influenced by various sub soiling and surface tillage combinations. Usually, sub soiling without T produced improved soil conditions and oat crop performance than the prevailing New Zealand practice of T without sub soiling. Sahaja (2015) studied the effect of tillage (zero tillage, minimal tillage and conventional tillage) on fodder yield and quality of oat. Conventional tillage recorded maximum dry fodder yield with 79.42 q/ha and green fodder yield with 342.23 q/ha.

The maximum 1000-grain weight (410.71 g) was observed in case of conventional tillage, while maximum total dry matter (32.13 Mg/ha) and grain yield (5.57 Mg/ha) was found in case of deep tillage as compared to minimum tillage. Tillage (deep & conventional) had pronounced effect on growth of maize (Khurshid *et al.,* 2006).

Malhi *et al.* (2007) reported that the lower plant population under ZT than CT in the establishment year did not essentially result in lower forage and seed yield of broom grass and alfalfa, suggesting that ZT can replace CT for forage production, and seeding time effect was mainly observed in the first year.

Ali *et al.* (2018) concluded that all the tillage methods be adopted or utilized for maize production in Makurdi sub-humid region and also the surface tillage should be utilized the most since it gave the highest grain yield of maize.

A study was conducted by Idowu *et al.* (2019) in an irrigated arid agro-ecosystem in south western USA, to compare two conservation tillage systems (strip tillage (ST) and no-tillage (NT)) to conventional, plow-based tillage (PT) system in Corn silage (*Zea mays* L.) In the first year there were significant yield differences in the fresh silage yield and moisture content of the silage, while silage yields at 65% moisture content (MC) were not significantly different between the tillage treatments. Significantly higher fresh corn silage yield was recorded for NT compared to PT, while ST was not significantly different from NT and PT. But in the second year there were no significant changes in fresh corn silage yield.

Khan *et al.* (2020) confirmed the superiority of conservation tillage over conventional tillage in improving soil status and thereby, crop performance. Cereal crop maize when grown under zero tillage produced maximum green forage yield (42.33 t/ha) and dry matter yield (7.84 t/ha).

The conventional tillage system performed better in terms of numbers of tillers/branches, leaf-to-stem ratio and green fodder yield than the conservation tillage system (Sohail *et. al.,* 2021).

Kumar *et al.* (2020) found that fodder sorghum based cropping systems comparatively highest sorghum green fodder yield was recorded in conventional tillage (CT) - conventional tillage (CT) + Sesbania as mulch (18.03 t/ha) but comparable yield also recorded with Minimum tillage (MT)-Conventional tillage (CT) + Sesbania as mulch (14.8) and Conventional tillage (CT) - Zero tillage (ZT) + Sesbania as mulch (16.5 t/ha).

Khan *et al.* (2021) revealed that zero tillage significantly performed well in ensuring best growth of all the fodder crops over others. However, crops showed variable response among each other regarding growth attributes due to its differential genetic makeup and morphological features. Accordingly, green forage yield also varied. Overall, the study confirms the efficacy of conservation tillage (zero tillage and/or minimum tillage) on growth of these fodder crops and soil moisture conservation in this region and agro-climatic condition over conventional tillage.

Effect of tillage practices on forage quality

Kumar (2016) reported that the content of N (at second cut) and B (at both the cuts) in forage oat were maximum under conventional tillage. Ca and Fe content were superior under zero tillage. P and K contents under conventional tillage were significantly higher compared to minimal and zero tillage. Uptake of N, P, K and Fe by forage oat was significantly higher under conventional tillage as compared to minimal tillage and zero tillage. Crude protein and crude fiber recorded under zero tillage at both the cuts remained at par with conventional tillage but significantly superior to minimal tillage. Further, crude fat and NFE (Nitrogen free extracts) contents under zero tillage were significantly higher compared to minimal as well as conventional tillage.

Baghdadi *et al.* (2012) found that the CP (crude protein) declined from 125 to 99 g/kg from the lowest to the highest plant density. Acid detergent fiber (ADF) increased from 156.9 to 197.5 g/kg from the lowest to the highest plant density. Dry matter digestibility (DMD) decreased from 689.9 to 655.0 g kg^{-1} from lowest to highest plant density. The reduction in forage quality with increasing plant density is attributed to the decline in leaf to stem ratio as well as reduced cob to whole plant ratio with increasing plant density. There was a significant interaction between plant density and tillage on CP concentration, where at the highest plant density, CP was significantly lower in the NT treatment compared to other tillage methods. Tillage methods showed no significant effects on the nutritive value of forage corn.

Mohammed (2013) conducted a research to study the contribution of tillage system (conventional and conservation tillage) and mechanical weeds control on forage quality of two leguminous species viz. Clitoria (*Clitoria ternatea*) and Siratro (*Macroptilium atropurpureum*) mixture under rainfed conditions for two consecutive seasons (2009-10 and 2010-11) in a semi-arid Savannah zone, at the University of Zalingei demonstration farm Western Darfur State, Sudan. Conventional tillage and mechanical weeds control significantly improved forage quality in terms of protein, phosphorus and fiber contents.

Kim *et al.* (2009) conducted an experiment to evaluate the effect of tillage system (tillage and no-tillage) on the forage quality of Italian ryegrass. Italian ryegrass cultivated with tillage (plough and rotary till) had lower TDN (total digestible nutrients) yield, and CP (crude protein) yield than no-tillage. However, there was no significant difference in CP content on tillage system. TDN were higher in tillage than no-tillage system ($p<0.01$).

Khan *et al.* (2020) reported that in crude protein yield, cowpea showed superiority over others specially when grown under zero tillage condition (1.071 t/ha).

Improvement in soil quality through conservation tillage

Intensive tillage has been a cause for degradation of crop land and, consequently, is a threat to food production and rural livelihoods (Derpsch *et al.*, 2010). Therefore, conservation is needed for improvement in soil quality and better environment. The ways to improve soil quality via conservation tillage are as follows:

Control of soil degradation

Soil is degraded through erosion caused either by wind or by water. Soil erosion has a negative impact on soil health, either through the loss of soil nutrients or soil C. It is considered as a global threat to the environment and food supply (Gregg and Izaurralde, 2010). Soil erosion prevention is important for the sequestration of C in soil. Wind erosion refers to a loss of the upper layer of the soil by wind, which occurs primarily in dry regions, whereas, in wet regions, water erosion covers all the forms of soil erosion by water, including sheet, gully, and rill–erosion (Kurothe *et al.,*2014). Soil erosion results in the deterioration of soil physical, chemical and biological properties and makes soil more vulnerable to decomposition (Kirkels *et al.,* 2014). The major events causing this decomposition are as follows:

- Lowering of the SOM and all the accompanying biological activity;
- Degradation of soil physical properties such as structure, porosity, and water holding capacity, due to reduced OM;

Conservation tillage helps in reduction of soil degradation by improving soil physical conditions like better aggregation due to enhanced level of organic matter and water holding capacity.

Reduction in Green House Gases (GHGs) Emissions from Soil

Initially, conservation tillage was adopted to control soil erosion and to increase SOM in the surface layer by developing a litter layer (Valentin *et al.*, 2008). Another important benefit for recommending conservation tillage was its potential to reduce GHG emissions from the soil. The following sections outline how GHG emissions are affected by physical, chemical and biological modifications that result from tillage practices.

Physical Modifications

Physical factors that regulate GHGs emissions during tillage are aeration, temperature, soil water content and the degree of mixing of crop residues within the soil matrix (Ussiri *et al.,* 2009). Jarecki and Lal (2006) showed that soil and air temperatures are positively correlated with CO_2 fluxes, and soil moisture content is negatively correlated with CO_2 fluxes. Soil with a good structure is a sink, and waterlogged soil is a source, for CH_4. Conservation tillage improves the activity of diverse species of soil fauna (e.g., earthworms and termites). Conservation tillage improves the soil hydrologic properties and soil tilth (Kladivko, 2001). Other physical properties changed by tillage and having an influence on soil emissions are soil porosity, bulk density, and aggregate improvement. Tangyuan *et al.* (2009) revealed that, between the 0 and 10 cm depths, total porosity was the main factor affected by tillage. CT increased the capillary porosity, but the non capillary porosity of subsoil-tillage was the highest.

Bulk Density

Bulk density is another soil physical property that can affect GHG emissions. A high bulk density is associated with compaction because of traffic by machinery (including sowing machines, sprayers, combines, and tractors) or grazing animals. The traffic reduces aeration under moist soil conditions. Bhandral *et al.* (2007) showed that N_2O fluxes can range from 2.62 to 61.74 kg N_2O-N ha^{-1} for compacted soil and 1.12–4.37 kg N_2O-Nha^{-1} for uncompacted soil.

Yamulki and Jarvis (2002) examined short-term compaction using open and closed chambers for tilled and compacted soil over a period of 3 weeks. It was found that total CO_2 emissions from the tilled soils were 1.8 times greater than those from the non tilled plots. Compaction increases emissions of N_2O and CH_4 by 3.5- and 4.4-fold, respectively, compared with emissions from uncompacted plots.

Aggregate Improvement

Aggregate stability is used as an indicator of soil structure. Stability results from the rearrangement of particles, flocculation, and cementation of mineral particles with organic and inorganic substances (Six *et. al*., 2000). In ploughed soils, stable aggregates breakdown and soil becomes structurally unstable so it can be dispersed readily either by wind or by rain. Large and stable aggregates are less erodible than small and weak aggregates, because small aggregates can be transported easily during runoff, which results in high soil losses of SOM. The homogenization and seasonal mixing of the plowed layer in tilled soils form weak aggregates, which are easily detached by rain regardless of size. Micro- and macro aggregates in undisturbed soils are stable and have slow turnover rates due to their high SOM content. Soil disturbance is less under NT, which limits diffusion of O_2. Soil enzymes are increased with NT, and they increase aggregate stability (Six *et al*., 2004). By contrast, under CT macro aggregates are heavily disrupted, and SOM is exposed to microbial decomposition (Six *et al*., 2000). Shepherd *et al.* (2001) found a loss of soil microbial-binding agents around aggregates after CT. Therefore, any disturbance in the aggregates disrupts soil physical, biological, and chemical processes, which further can affect aggregate stability and SOM.

Chemical Interactions

Chemical properties of soil like pH and the quantity and quality of SOC are factors that play a role in influencing the emission of GHGs and C sequestration. To increase the SOC pool, sustainable management practices must be adopted because the stable or non labile fraction of SOC is an important indicator of soil quality and agronomic sustainability (Gulde *et al*., 2008). SOC through its functional role supplies nutrients, enhances soil/plant water reserves, stabilizes soil structure, recycles nutrients, and increases soil-buffering capacity, all of which contribute to influencing crop productivity and environmental quality (Hobbs *et al*., 2008).

Decrease in CO_2 Emissions from Soils

The increase in atmospheric CO_2 is mainly attributed to anthropogenic activities. Between the 1990s and 2000–06, fossil fuel CO_2 emissions increased from 1.3% to 3.3% per year (Canadell *et al*., 2007). From 1850 to 2006, 158 Gt C as CO_2 was emitted through land use change (largely as deforestation and wood harvest), and 330 Gt C was emitted as CO_2 from fossil fuel and cement emissions (Canadell *et al*., 2007). Tillage strongly affects the flux of CO_2 from soil, when tillage is going on it speeds up oxidation of SOC to release CO_2 by improving the soil aeration, increasing contact between soil and crop residues, and exposing aggregate-protected SOM to microbial attack (Chivenge *et al*., 2007). Alvaro-Fuentes *et al.* (2007) conducted a study in a semiarid Mediterranean agro-ecosystem, and they showed that CO_2 flux was 3-15 times higher after tillage than before. Reicosky *et al.* (2008) reported that the CO_2 concentration rising from agricultural activities was 3.3% from no-till plots compared to 1.4% in the deep-plowed plots.

Control of Methane (CH_4) Emissions from Soils

Different responses of soil CH_4 fluxes from aerobic soils have been reported from various soil types belonging to different regions. The key enzymes responsible for CH_4 oxidation under aerobic conditions are produced by methanotrophic bacteria (Heutsch, 2001). Methane contributes 20% to global warming, being a 25 times more potent than CO_2 (EPA, 2015). Agriculturally related anthropogenic CH_4 emissions come from paddy (rice) cropping (Han *et al.*, 2016), biomass burning and land use change to allow crop production (e.g., deforestation). CH_4 oxidation from arable agricultural soils has a more negative effect compared to that from woodland soils due to the disturbance in soil structure associated with agricultural tillage (Heutsch, 2001). Ussiri *et al.* (2009) conducted a study to evaluate the effect of NT, chisel till, and moldboard plowing and found that NT acted as a sink for CH_4; on average, 0.32 kg CH_4-C ha^{-1} $year^{-1}$ was oxidized with NT, while chisel till and moldboard plowing resulted in emission of CH_4. Yet, other studies have also analyzed the differences between the total flux of CH_4 from CT and NT, and they report that differences in CH_4 fluxes are relatively small or insignificant (Jacinthe and Lal, 2005).

Effect of tillage practices on Carbon Sequestration in forage crops

Soil organic carbon (SOC) has also been identified as a possible C sink for sequestering atmospheric carbon dioxide, in addition to its significant influence on soil quality and therefore crop productivity. Tillage systems effect carbon sequestration. Dixit *et al.,* 2019 evaluated nine combinations of three tillage practices including conventional tillage (CT), minimum tillage (MT) and zero tillage (ZT) in fodder sorghum (*Sorghum bicolor*) + cowpea (*Vigna unguiculata*) – wheat (*Triticum durum*) cropping system for 5 years (2009–2014) on clay loam soil under limited irrigation. Continuous ZT practices significantly improved surface soil organic carbon. Carbon sequestration rate and soil organic carbon stock were relatively more under ZT than CT-CT practice. The conversion of annually cultivated land to forage grasses has potential to increase C and N sequestration.

Chan *et al.* (2011) in their study in a long-term crop/pasture experiment at a site with initial high SOC showed that the rate of SOC change in different treatments ranged from –278 to +257 kg C/ha/year over 0–0.3 m soil depth. Under continuous cropping, even under conservation agriculture practices of no-tillage, stubble retention, and crop rotation, the high initial SOC stock (0–0.3 m) present after a long-term pasture phase was, at best, maintained but tended to decrease with increased tillage. Su (2007) investigated the short-term changes in SOC) and N pools after annual crops were converted to alfalfa (*Medicago sativa* L. Algonguin) forage for 4 years. Organic C, POM-C, and POM-N contents in the surface layer were significantly greater in alfalfa field than in adjacent cropland. The result of this reveals that the conversion of crops to alfalfa should be widely used to sequester C and improve soil quality.

CONCLUSION

Losses of SOC and deterioration in other soil properties exaggerated where conventional tillage was engaged; whereas, conservation tillage improve soil quality. When conventional tillage is replaced by conservation tillage CO_2 and CH_4 emissions from soil are reduced. Conservation tillage leads to improvement in soil health, plant growth and the environment. It appears that conservation tillage in forage crops realize soil C sequestration benefit. SOC through its functional role supplies nutrients, enhances soil/plant water reserves, stabilizes soil structure, recycles nutrients, and increases soil-buffering capacity, all of which contribute to influencing crop productivity and environmental quality. Forage crop production could be increased by adopting appropriate tillage operation. Macro- and micronutrients, fiber and protein contents are changed in silage by means of different tillage practices.

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